Submitted by:

ITERIS®

ITS INNOVATIVE IDEA PROGRAM
ARTERIAL TRAVEL TIME MONITORING SYSTEM USING BLUETOOTH PROJECT

User Manual

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GLOSSARY OF ACRONYMS

AC – Alternating Current
BT - Bluetooth
dBi – Decibel Isotropic
DC – Direct Current
DNS – Domain Name System
DSRC – Dedicated Short Range Communication
Ghz - Gigahertz
GPS – Global Positioning System
IP – Internet Protocol
ITS – Intelligent Transportation Systems
kbps – Kilobytes Per Second
LAMP – Software including Linux, Apache, MySQL, and PHP
LAN – Local Area Network
MAC – Media Access Control
ms - Millisecond
NTP – Network Time Protocol
OS – Operating System
PHP – Hypertext Preprocessor
RF – Radio Frequency
RSU – Road Side Units
TCP/IP – Transmission Control Protocol/Internet Protocol

1 INTRODUCTION

1.1 PURPOSE

The purpose of this document is to provide Hennepin County Public Works and the Minnesota Department of Transportation (Mn/DOT) with the necessary knowledge and basic instructions for using StreetWAVE Bluetooth receivers with a third-party hosted web interface in the collection of travel time data along the CSAH 81 corridor. The Arterial Travel Time Monitoring System Using Bluetooth Technology Project is a pilot deployment demonstration funded by Mn/DOT's 2009 ITS Innovative Idea Program. This pilot deployment focused on the demonstration of the system's hardware, communications, system software and collection of Bluetooth data along CSAH 81 (Hennepin County) to determine travel times along test segments of the corridor.

1.2 OVERVIEW OF THE ARTERIAL TRAVEL TIME MONITORING SYSTEM USING BLUETOOTH TECHNOLOGY

The Arterial Travel Time Monitoring System Using Bluetooth Technology is an "infrastructure-based probe" system that utilizes Bluetooth technology to track the progress of vehicles in real-time along an arterial corridor. The unique identifier (i.e., "signature") for each vehicle is the MAC address for a Bluetooth device located within the vehicle (e.g., hands free communications for cell phones, a laptop or other Bluetooth-enabled device). The MAC addresses are read and time-stamped by Bluetooth receivers as the vehicles travel along the CSAH 81 corridor. This information is automatically transmitted to a central server (StreetWAVE) where a software algorithm matches the vehicle signatures and time stamps collected at six different locations along CSAH 81. Segment travel times for each vehicle identified by the system are calculated. Then the individual segment travel times of multiple vehicles are combined to calculate the average travel time and average speed for each segment.

1.3 LOCATIONS OF BLUETOOTH RECEIVERS

The deployment of wireless Bluetooth receivers (also known as Road Side Unit or RSU) for the Arterial Travel Time Monitoring System Using Bluetooth Technology project is limited geographically to six (6) intersections along CSAH 81 between Brooklyn Park on the north end and Robbinsdale on the south end as shown in **Table 1**:

TABLE 1 -- LOCATIONS OF BLUETOOTH RECEIVERS ON CSAH 81

Intersection	Mounting Location	Captured Traffic
CSAH 81/Greenhaven Dr.	NE and SW corners (2)	NB and SB
CSAH 81 /71st Avenue	SW Corner	NB and SB
CSAH 81 / 63rd Avenue	NE corner	NB and SB
CSAH 81 / Bass Lake Rd	SW corner	NB and SB
CSAH 81 / 42nd Avenue	NE corner	NB and SB
CSAH 81 / 36th Avenue	NW and SE corners (2)	NB and SB

2 ARTERIAL TRAVEL TIME MONITORING SYSTEM HARDWARE

The Arterial Travel Time Monitoring System installed along CSAH 81 consists of the following hardware:

- Eight (8) Savari Networks "StreetWAVE" Bluetooth Receivers
- Eight (8) 2.4 GHz 6 dBi Omni-Directional Wireless LAN Bluetooth Antennas
- Eight (8) Wireless 5 Ghz Dual Band Omni Antennas
- Six (6) 3G Antennas with Brackets for Pole Mounting
- Eight (8) Phoenix Contact Power Converter Units
- Eight (8) Cabinets to House Power Converter Units
- Power and Ethernet Cables for each StreetWAVE Device
- Band-It Strapping for Pole Mounting

A picture of each of the hardware components installed for the Arterial Travel Time Monitoring System is shown in Figures 1, 2, and 3.

FIGURE 1. STREETWAVE RSU WITH 3G ANTENNA

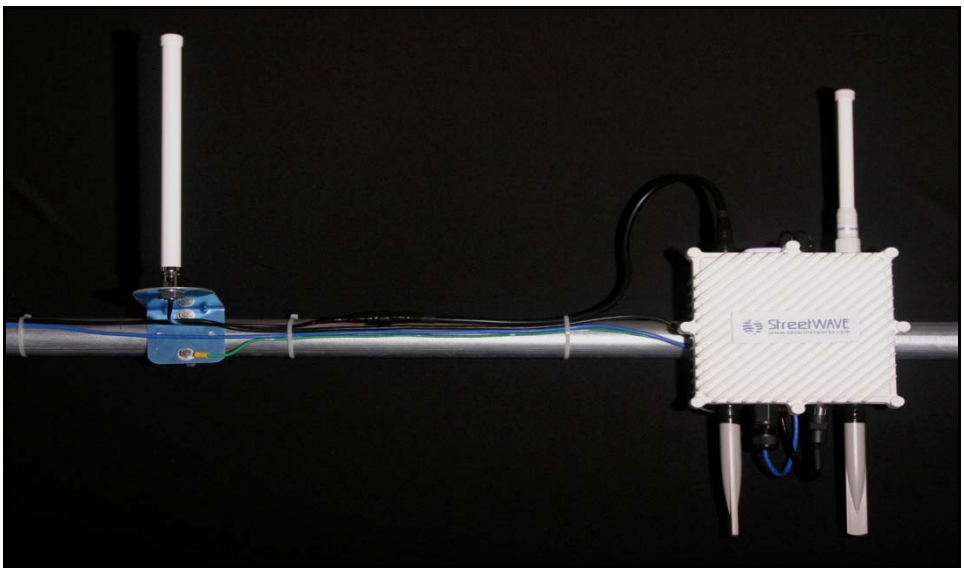


FIGURE 2. RSU ETHERNET AND POWER CONNECTIONS

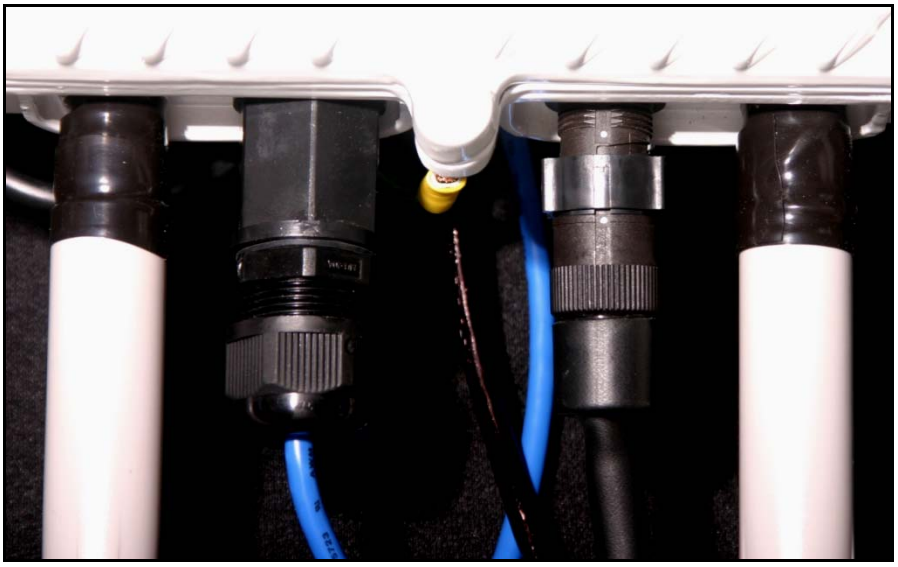


FIGURE 3. PHOENIX CONTACT AC /DC POWER CONVERTER

2.1 POWER SUPPLY

The StreetWAVE Bluetooth device uses 24 volt (V) DC power. Each traffic signal pole has been supplied with a field hardened 120 V AC to 24 V DC Phoenix Contact power converter unit to allow the traffic signal power supply to step down to the low voltage Bluetooth device.

3 LEASED COMMUNICATIONS

A wide array of communication alternatives can be used for transmitting the MAC addresses, time stamps, and location information to a central location for subsequent processing. Due to the lack of an existing county-owned communications network, a 3G wireless provider was installed at each intersection. This solution provided a reliable communications network while minimizing costs and impact to the implementation schedule. Sprint has provided the wireless service at each of the six project intersections since May 2010 with the installation of a 3G modem. Each intersection

communicates independently with the central server. This approach was chosen to ensure that no single point of communications failure will occur during system operations. Wireless service from Sprint's 3G network was tested during field surveys, which were conducted prior to the system's installation in May 2010. Those surveys indicated the following results:

- At all device locations, 3G download speeds ranged from 500kbps to 1.5Mbps. Upload speeds ranged from 200kbps to 550kbps. This was more than enough to satisfy the project data communication requirements.

- Network latency at all sites was measured between 57ms and 117ms. This reading was more than enough to satisfy project requirements.

Wi-Fi interference was also measured at each of the project intersections. Based on the field survey performed, it was determined that interference would not significantly affect the communications performance in the field at any location.

At Greenhaven Drive and CSAH 81, there are two RSUs in the same intersection. One of these RSUs connects to the StreetWAVE server using a 3G interface (SWGreenhavenN). The 2nd RSU (SWGreenhavenS) uses a Wi-Fi connection to connect to the server through the SWGreenhavenN RSU. This configuration is also used for the two RSUs in the 36th Avenue intersection.

4 INITIAL CONFIGURATION

The StreetWAVE Road Side Unit (RSU) and the StreetWAVE server require minimum network configuration. The RSU sends collected BT device data to the server via TCP/IP. It relies on Internet access to obtain DNS and NTP information. If the RSU is deployed on a private network, then it is necessary to configure access to the Internet through any firewall.

4.1 RSU SETUP/CONFIGURATION

The RSU is configured to dynamically obtain its IP networking configuration:

- IP Address
- Network Mask
- Default Gateway

The StreetWAVE server address is statically configured. Optionally, the DNS server and the Network Time Protocol (NTP) server address can be statically configured.

4.2 STREETWAVE INSTALLATION/CONFIGURATION

The StreetWAVE server uses the LAMP software bundle consisting of Linux, Apache, MySQL and PHP. Linux is the OS of the server; Apache is used as the web server, MySQL for the database and PHP as the scripting engine. The server can be accessed over the network using any standard supported web browser. The minimum screen resolution on the client side is 1280 x 800.

Once the RSUs and the StreetWAVE are configured and the communications link enabled, the StreetWAVE server auto-discovers the RSUs along with their locations and operational status (details in the StreetWAVE Overview tab section). Once the RSUs are discovered, it is expected that the user provisions RSU segments from the RSU segments tab. All travel time related information can now be viewed for specific RSU segments.

The StreetWAVE server is designed to be intuitive and self-explanatory. The following design aspects are common to all the various features and menu options available:

- A help window is displayed when the mouse pointer is placed across any text in bright blue.
- A color palette is available next to all data types such that the individual color of the plotted line/dots can be changed.
- The plotted graph type can be chosen to be either “line” or “dots”.
- Certain graph data can be downloaded either in ‘csv’ or ’xml’ format.
- ‘Reset’ button loads all default values for that page.

5 DATA PROCESSING

Each StreetWAVE RSU continuously scans for the presence of any BT device within its radio transmission range. As BT devices enter and leave the radio transmission range of the RSU, the RSU typically detects and records their presence multiple times. These records consist of the MAC address of the BT device, the time stamp and the ID of the RSU. It is necessary to separate records of the BT devices detected multiple times from records of BT devices that leave and return. The objective is to distinguish between vehicles that linger in the vicinity of the RSU from vehicles that leave and return.

This is done by aggregating all records for a particular BT device with time stamp difference of less than 60 seconds. In other words, if a BT device record is within 60 seconds of the previous record, then these records are considered an indication of multiple detections of the same vehicle within the vicinity of the RSU, but not a vehicle that leaves and returns. A gap in BT device records of more than 60 seconds is considered to be an indication that the vehicle left the vicinity of the RSU.

The basis for further travel time processing is the aggregate block of all BT device records separated by less than 60 seconds. This block has an identifiable start time (first time the BT device was detected) and end time (last time the BT device was detected).

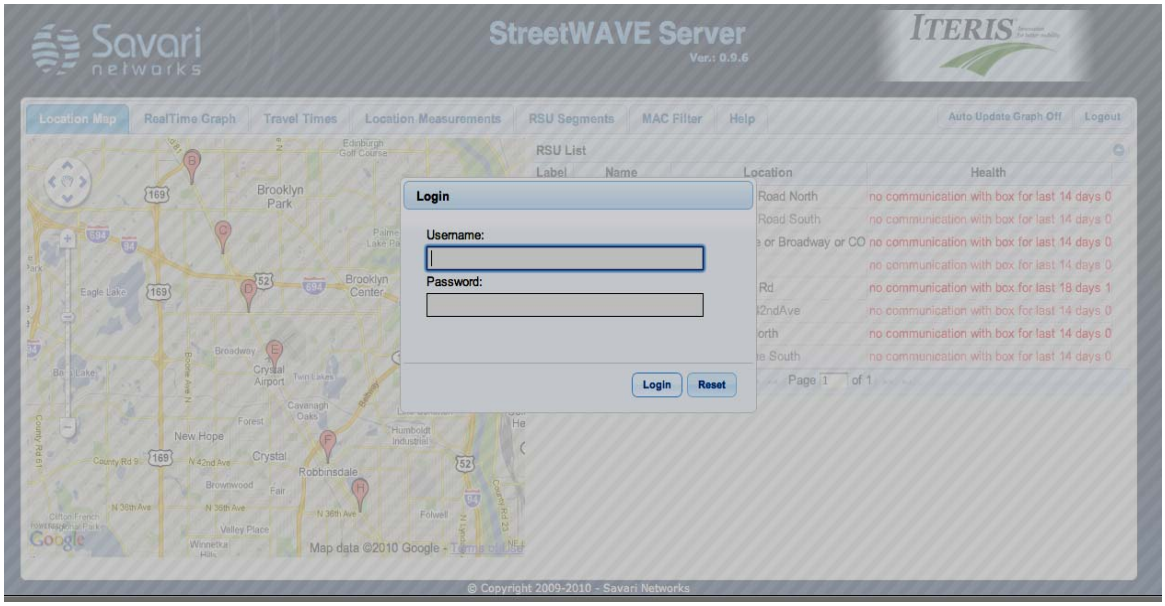
5.1 User Interface

5.1.1 Interface Access

The StreetWAVE Bluetooth reader system is available via the web-based interface at http://minneapolis.savarinetworks.com. It provides access to project data collected along CSAH 81 in Hennepin County.

The user is required to log-in with a username and password as seen in **Figure 4**. The current username and password is "savari" for both fields.

FIGURE 4. STREETWAVE SERVER LOG-IN SCREEN



5.1.2 *StreetWave Server Main Menu/Tabs*

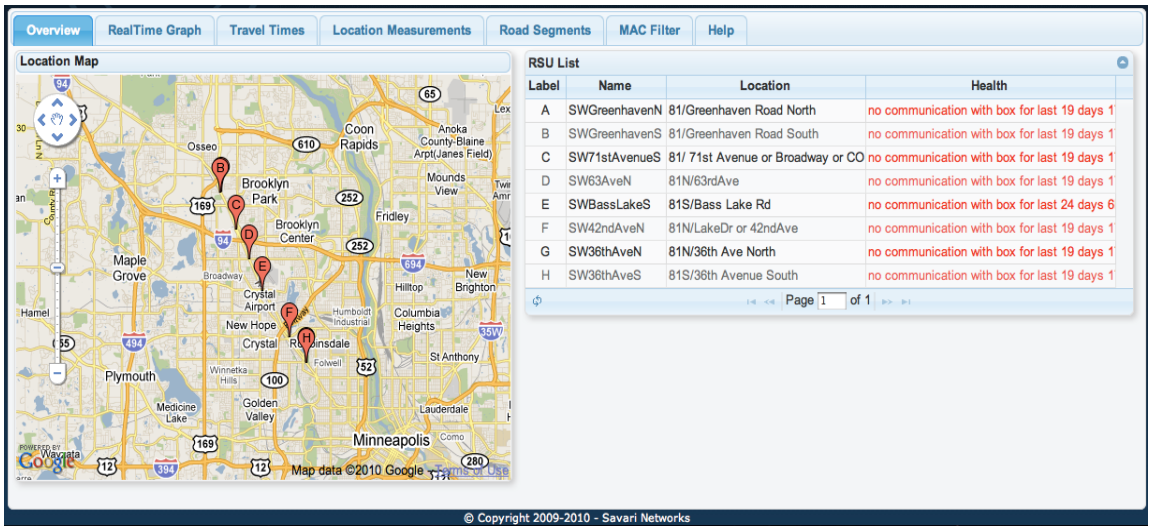
After log-in, the default page displayed is the first tab of the StreetWAVE server, which is called "Overview". In addition to the "Overview" tab, there are six other tabs.

- Real Time Graph
- Travel Times
- Location Measurements
- Road Segments
- MAC Filter
- Help

In addition, there is an "Auto Update Graph Off" and "Logout". The former button can be toggled to "on" or "off" to enable auto graph updates triggered on any input parameter change. By default, this feature is turned off.

5.1.3 *Overview*

FIGURE 5. STREETWAVE OVERVIEW SCREEN


Overview
RealTime Graph
Travel Times
Location Measurements
Road Segments
MAC Filter
Help
Location Map
RSU List
Label Name Location Health
A SWGreenhavenN 81/Greenhaven Road North no communication with box for last 19 days 1
B SWGreenhavenS 81/Greenhaven Road South no communication with box for last 19 days 1
C SW71stAvenueS 81/ 71st Avenue or Broadway or CO no communication with box for last 19 days 1
D SW63AveN 81N/63rdAve no communication with box for last 19 days 1
E SWBassLakeS 81S/Bass Lake Rd no communication with box for last 24 days 6
F SW42ndAveN 81N/LakeDr or 42ndAve no communication with box for last 19 days 1
G SW36thAveN 81N/36th Ave North no communication with box for last 19 days 1
H SW36thAveS 81S/36th Avenue South no communication with box for last 19 days 1
Page 1 of 1
Minneapolis
Map data ©2010 Google
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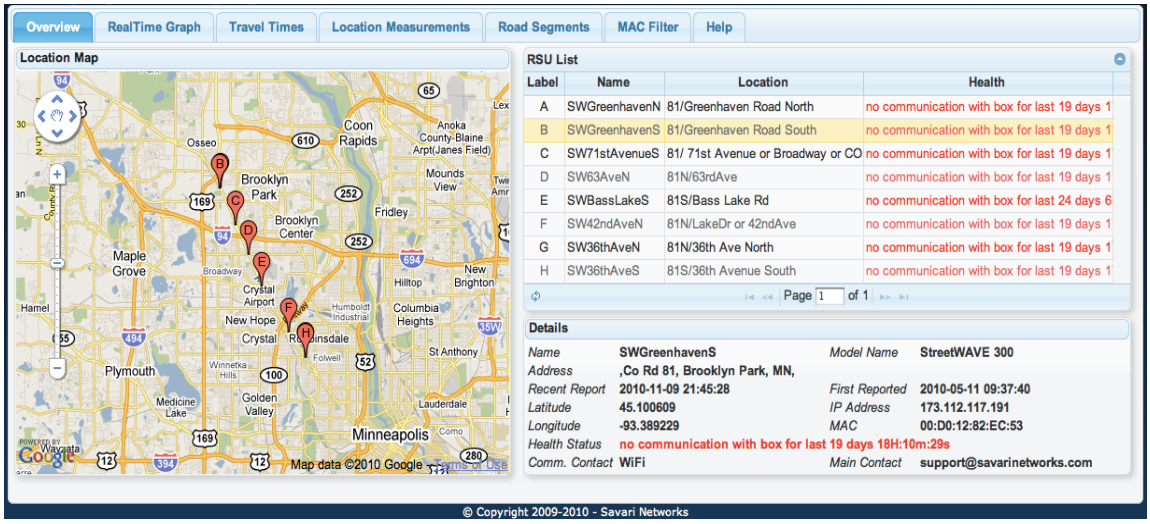
The StreetWAVE default page (Overview tab) provides an overview of the CSAH 81/Hennepin County system, as shown in **Figure 5**. The Overview tab shows the location of each StreetWAVE reader on a system map, its current operational status, and other basic operational information. The server also allows users to monitor the system and to generate reports from data gathered through the system's readers installed in the field.

Clicking on a particular RSU icon will bring up detailed information, including location (latitude, longitude, IP address, etc).

FIGURE 6. OVERVIEW SCREEN WITH RSU DETAILS


Overview
RealTime Graph
Travel Times
Location Measurements
Road Segments
MAC Filter
Help
Location Map
RSU List
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A SWGreenhavenN 81/Greenhaven Road North no communication with box for last 19 days 1
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D SW63AveN 81N/63rdAve no communication with box for last 19 days 1
E SWBassLakeS 81S/Bass Lake Rd no communication with box for last 24 days 6
F SW42ndAveN 81N/LakeDr or 42ndAve no communication with box for last 19 days 1
G SW36thAveN 81N/36th Ave North no communication with box for last 19 days 1
H SW36thAveS 81S/36th Avenue South no communication with box for last 19 days 1
Page 1 of 1
Details
Name SWGreenhavenS
Address ,Co Rd 81, Brooklyn Park, MN,
Recent Report 2010-11-09 21:45:28
Latitude 45.100609
Longitude -93.389229
Health Status no communication with box for last 19 days 18H:10m:29s
Comm. Contact WiFi
Model Name StreetWAVE 300
First Reported 2010-05-11 09:37:40
IP Address 173.112.117.191
MAC 00:D0:12:82:EC:53
Main Contact support@savarinetworks.com
Map data ©2010 Google
© Copyright 2009-2010 - Savari Networks

Each of the Overview icons displayed at the six intersections along the CSAH 81 corridor has the ability to demonstrate the real-time operational status of the StreetWAVE units. Icons are displayed in one of three colors—green, red or yellow—depending upon the current state of operation of the StreetWAVE unit at a particular location:

- **Green** indicates that the StreetWAVE device is online and functioning normally.
- **Red** indicates that the StreetWAVE device is offline and there is no communication with the StreetWAVE server
- **Yellow** indicates that StreetWAVE device is in an alarm state with limited communication to the StreetWAVE server.

5.1.4 REALTIME GRAPH

The tab labeled "RealTime Graph" displays real-time travel time for a particular RSU segment. The window displays all current travel time information averaged every 15 seconds. The chart is updated/refreshed every 15 seconds. This means that all travel time data from matched Bluetooth devices within a 15 second interval are shown as one average value. Currently, the maximum travel time displayed needs to be within one hour (60 minutes). The window shows the travel time for the last 60 minutes with the absolute time referenced on the x-axis as the time corresponding to the destination RSU.

FIGURE 7. STREETWAVE REALTIME GRAPH SCREEN

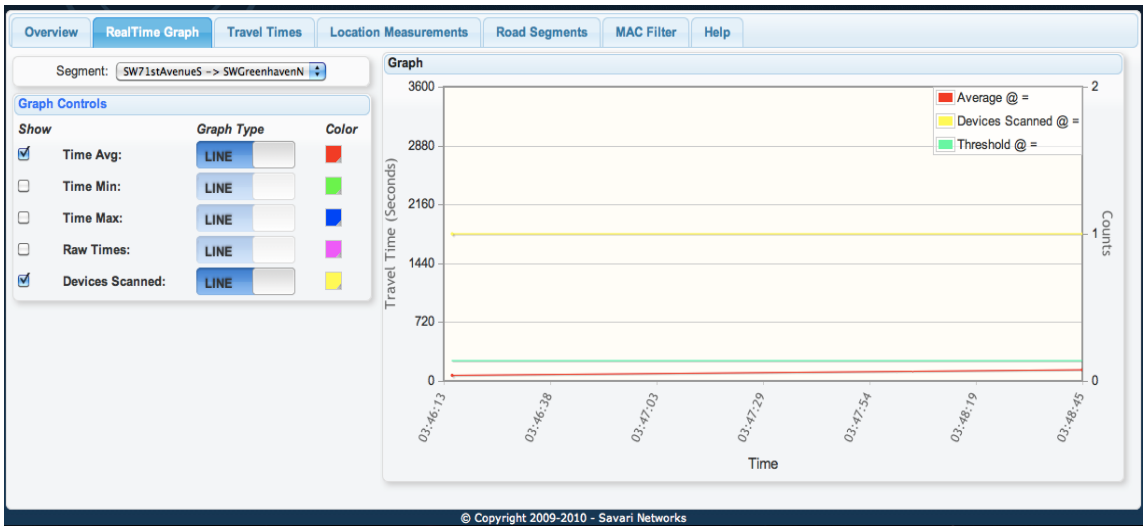


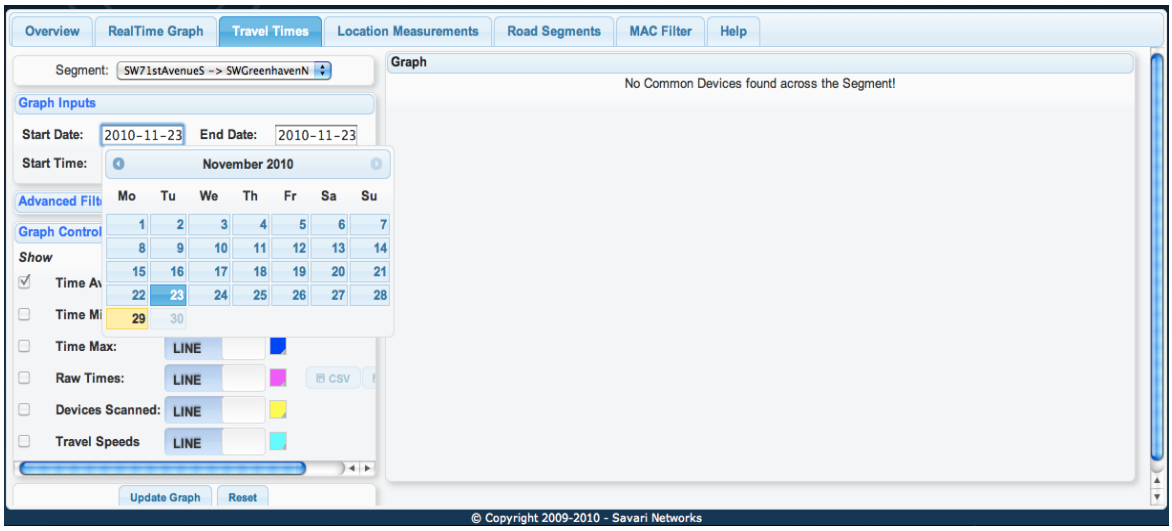
Figure 7 graphically displays the travel times and matched BT devices. The light green horizontal line represented on the graph is the "Threshold Travel Time", as described in Section 5.1.9, "RSU Segments".

5.1.5 StreetWAVE Travel Time Tab Options

The basic concept of calculating travel time follows a simple logic of finding a BT device that has been seen at both the Source RSU and the Destination RSU. The travel times are then calculated by taking the difference in time that the device was seen at each RSU. The plot is then shown on a simple chart with the Y-axis corresponding to travel time and the X-axis corresponding to the times at the source RSU. The travel times can be averaged over various time-intervals that are user selectable within the "Advanced Filters" box within the "Travel Times" tab. The various parameters of a travel time query are:

- Start date/time at source RSU and end date/time at destination RSU
- Maximum expected travel time (default to 1 hour)
- "Time Type" – default to "Last – First" (Last scan at source RSU and First scan at destination RSU).

FIGURE 8. TRAVEL TIME/GRAPH INPUTS > START DATE SCREEN



Start date and start time drop down options are shown in **Figure 9**. The former shows the current month whereas the latter displays options from midnight (12:00 AM to 11:45 PM).

FIGURE 9. TRAVEL TIME GRAPH INPUTS > START TIME SCREEN

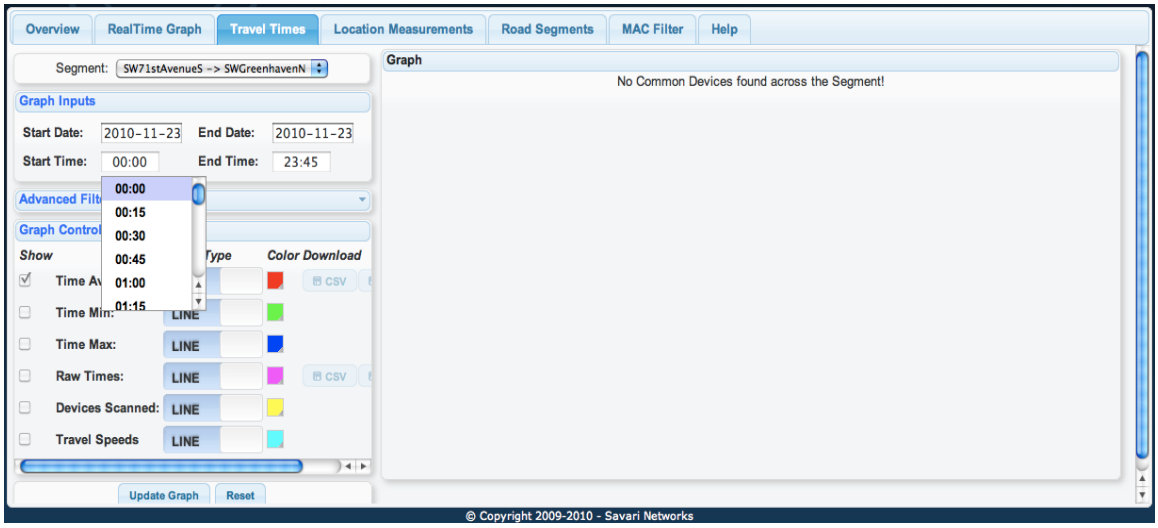
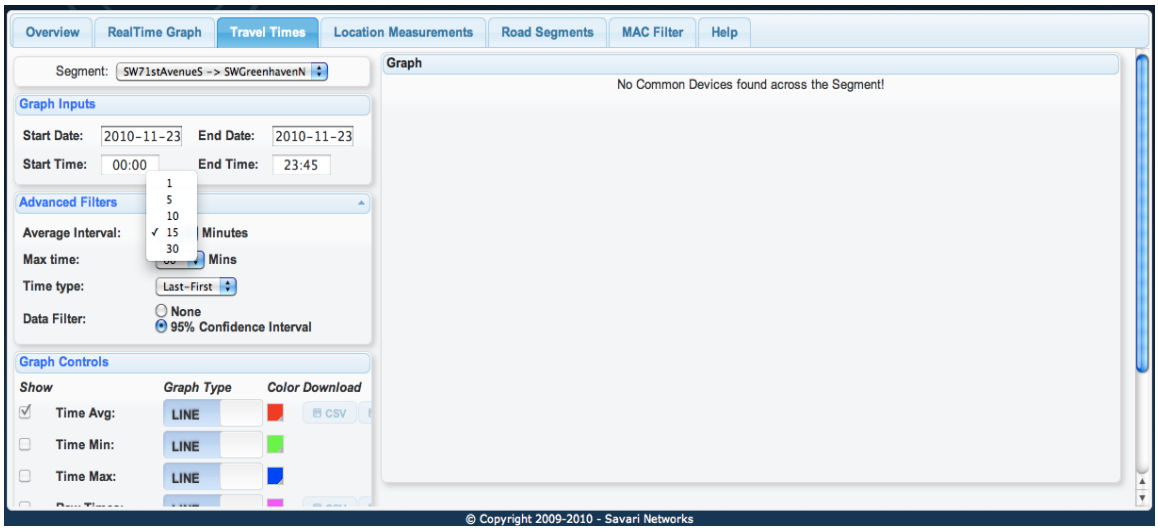
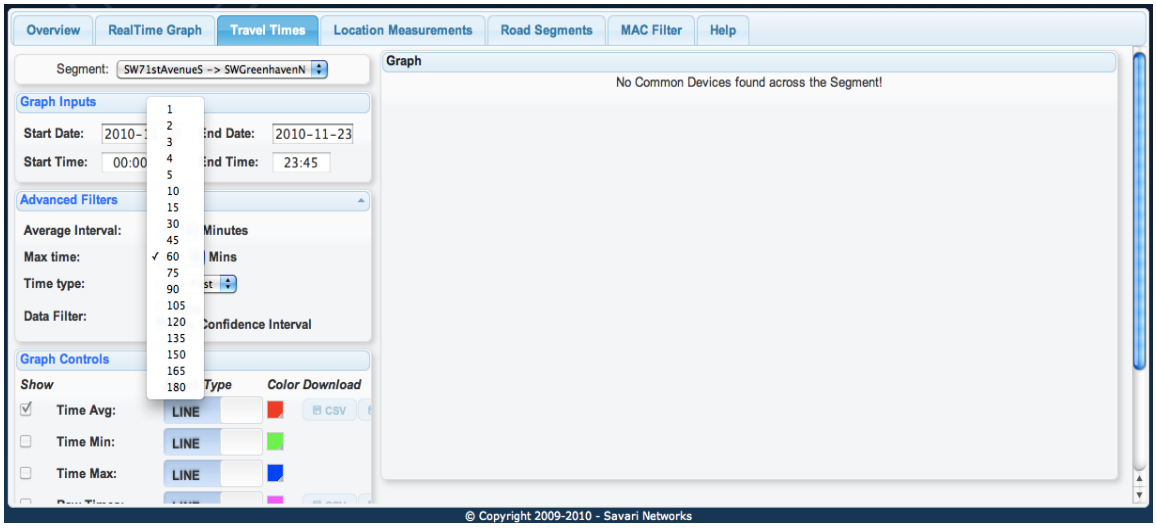


FIGURE 10. TRAVEL TIME, ADVANCED FILTERS > AVERAGE INTERVAL SCREEN



The Average Interval, as shown in **Figure 10**, is the interval of time within which chart data is averaged and displayed. A value of 15 minutes (default) indicates that data represented against the y-axis (travel time, speed and device counts) is averaged over the 15 minute interval and represented on the x-axis against the absolute time (corresponding to the start time of the interval, e.g., 12.00 PM, 12.15 PM, etc).

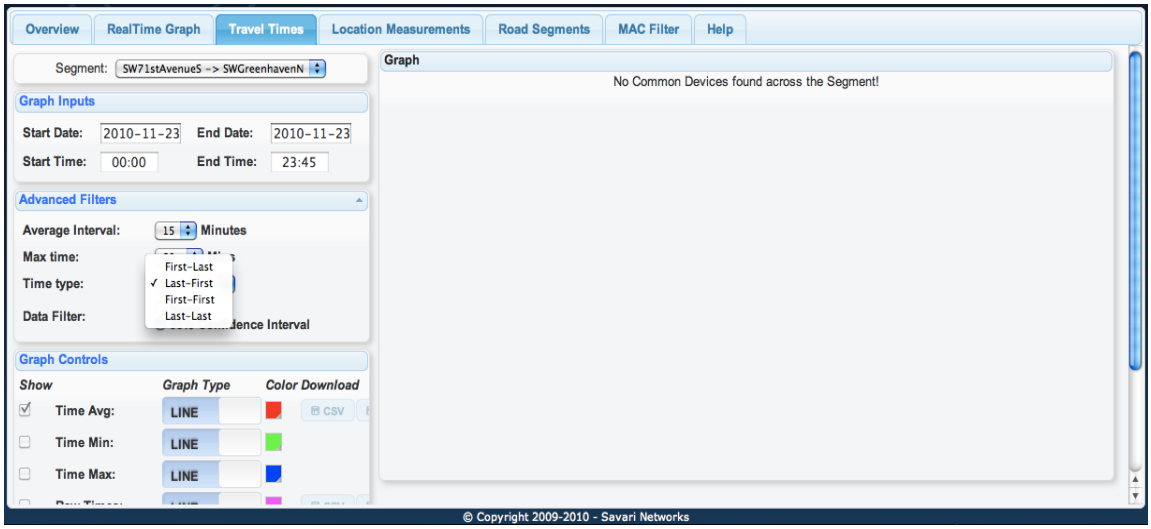
FIGURE 11. TRAVEL TIMES, ADVANCED FILTERS > MAX TIME SCREEN



The option "**Max Time**" (default 60 minutes) shown in **Figure 11** corresponds to a boundary condition wherein the user can select the maximum travel time to be

displayed within the graph. Matched MAC addresses that have a travel time beyond this chosen value will be filtered and not shown in the graph.

FIGURE 12. TRAVEL TIMES, ADVANCED FILTERS > TIME TYPE SCREEN



The "**Time Type**" represents the scan interval to be considered for calculation of travel time between two RSUs. **Figure 12** shows an example of the different "**Time Types**". The scan interval can be either based on the "first-seen" or "last-seen" time stamp of the BT device. Depending on the location of the RSU and other conditions such as congestion, etc., a particular BT device may be seen at an RSU for a longer time. In a free traffic flow scenario, it is conceivable that a BT device may only be seen once. Travel time based on the source RSU first-seen to destination RSU last-seen yield the highest averages whereas source RSU last-seen to destination RSU first-seen yield the lowest averages. The default is a condition of "last seen to first seen".

The "**Data Filter**" controls the quality of the graph by including or excluding outliers. If "None" is selected, this means that the graph will display raw data. The "95% Confidence Interval" is a filter applied when a graph is wanted without outliers. The filter is a confidence filter which works on elimination of the last 5% of the travel times within a distribution of the frequency of occurrence of a particular travel time.

"**Graph Controls**" control the specific graph to view. The user can choose any or a combination of the following:

- *Time Avg* – Draws a graph showing average travel times
- *Time Min* – Draws a graph showing minimum travel times within the chosen time interval

- *Time Max* – Draws a graph showing maximum travel times within the chosen time interval
- *Raw Times* – Draws a graph showing the raw (actual) points/data of the travel times
- *Devices Scanned* – Shows a count of the number of matched BT devices
- *Travel Speeds* – Shows a graph of the average speeds within the chosen interval.

5.1.6 VIEWING STREETWAVE TRAVEL TIME

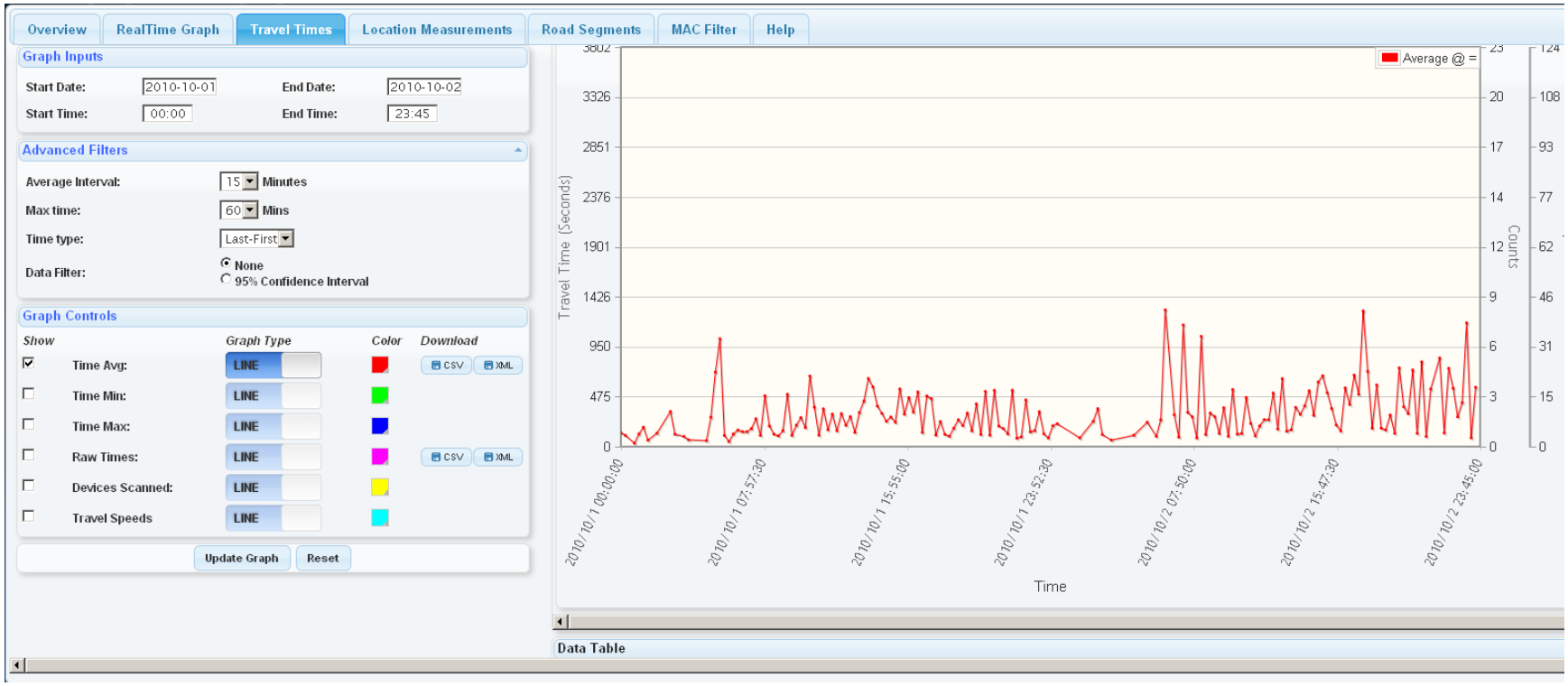
Once a query is entered with the above-mentioned criteria, the server collates all matched BT device travel times. The collated data is grouped within the "Average Interval" specified in the "**Advanced Filters**" box and is defaulted to 15 minutes.

Note that in all graphs the user can zoom into a portion of the graph by selecting it. Double-clicking on the graph will restore the original graph view.

Figure 13 and Figure 14, respectively, show average travel time graphs with and without the data filter. As expected, the graph without the data filter shows longer travel times which are discarded as outliers with the data filter.

FIGURE 13. AVERAGE TRAVEL TIME WITH DATA FILTER SCREEN

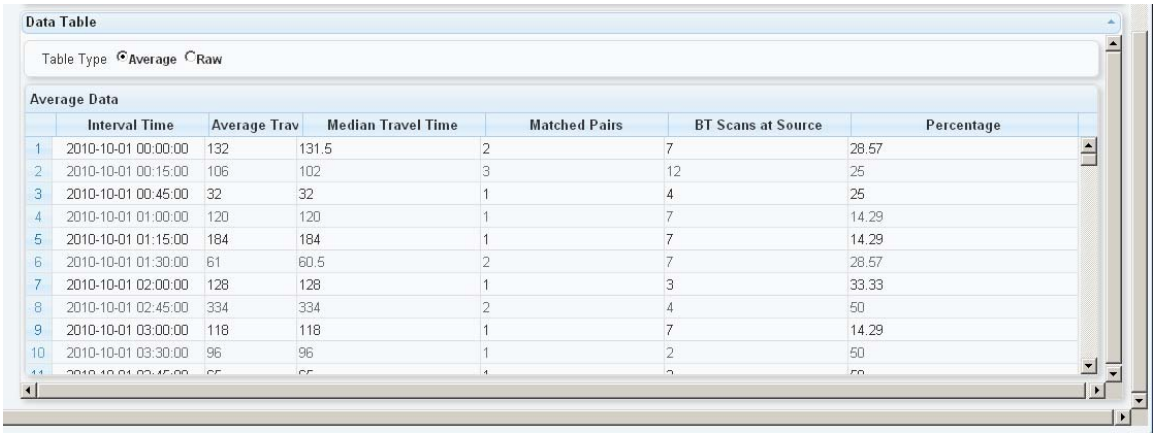
FIGURE 14. AVERAGE TRAVEL TIME WITHOUT DATA FILTER SCREEN



A tabular display is also available to users. In the bottom right corner of the page there is an arrow pointing to the bottom of the page. A table is displayed when the arrow is clicked. The user is able to select from two types of tables (Average' or 'Raw'), which can be seen in **Figure 15**. The 'Average' table displays the following information:

- **Interval Time** – The period of time the user wishes to view results. The interval time can be changed in the Advanced Filters section (see **Figure 10**).
- **Average Time** – The average travel time of all captured vehicles during the given interval time.
- **Median Travel Time** – The median travel time over the given interval time. Matched Pairs – The number of Bluetooth MAC addresses found at both the source RSU and the destination RSU.
- **BT Scans at Source** – The number of Bluetooth MAC addresses found at the source RSU.
- **Percentage** – The percentage of Matched Pairs to BT Scans at Source RSU.

FIGURE 15: TRAVEL TIMES: TABULAR DISPLAY USING THE AVERAGE TABLE

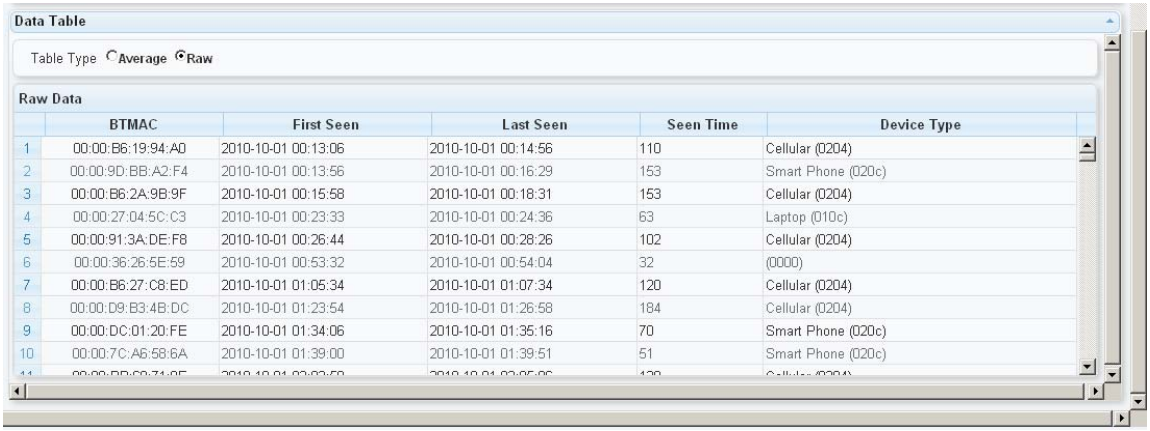


	Interval Time	Average Trav	Median Travel Time	Matched Pairs	BT Scans at Source	Percentage
1	2010-10-01 00:00:00	132	131.5	2	7	28.57
2	2010-10-01 00:15:00	106	102	3	12	25
3	2010-10-01 00:45:00	32	32	1	4	25
4	2010-10-01 01:00:00	120	120	1	7	14.29
5	2010-10-01 01:15:00	184	184	1	7	14.29
6	2010-10-01 01:30:00	61	60.5	2	7	28.57
7	2010-10-01 02:00:00	128	128	1	3	33.33
8	2010-10-01 02:45:00	334	334	2	4	50
9	2010-10-01 03:00:00	118	118	1	7	14.29
10	2010-10-01 03:30:00	96	96	1	2	50

The 'Raw' table can be seen in **Figure 16**. The 'Raw' table provides the following information:

- **BTMAC** – The MAC address that has been detected between these locations.
- **First Seen** – The date and time that the MAC address was seen at the source RSU location
- **Last Seen** - The date and time that the MAC address was seen at the destination RSU location
- **Seen Time** – The amount of time from when the MAC address was First Seen to the time it was Last Seen.
- **Device Type** – The type of device from which the MAC address was pulled.

FIGURE 16: TRAVEL TIMES: TABULAR DISPLAY USING THE RAW TABLE

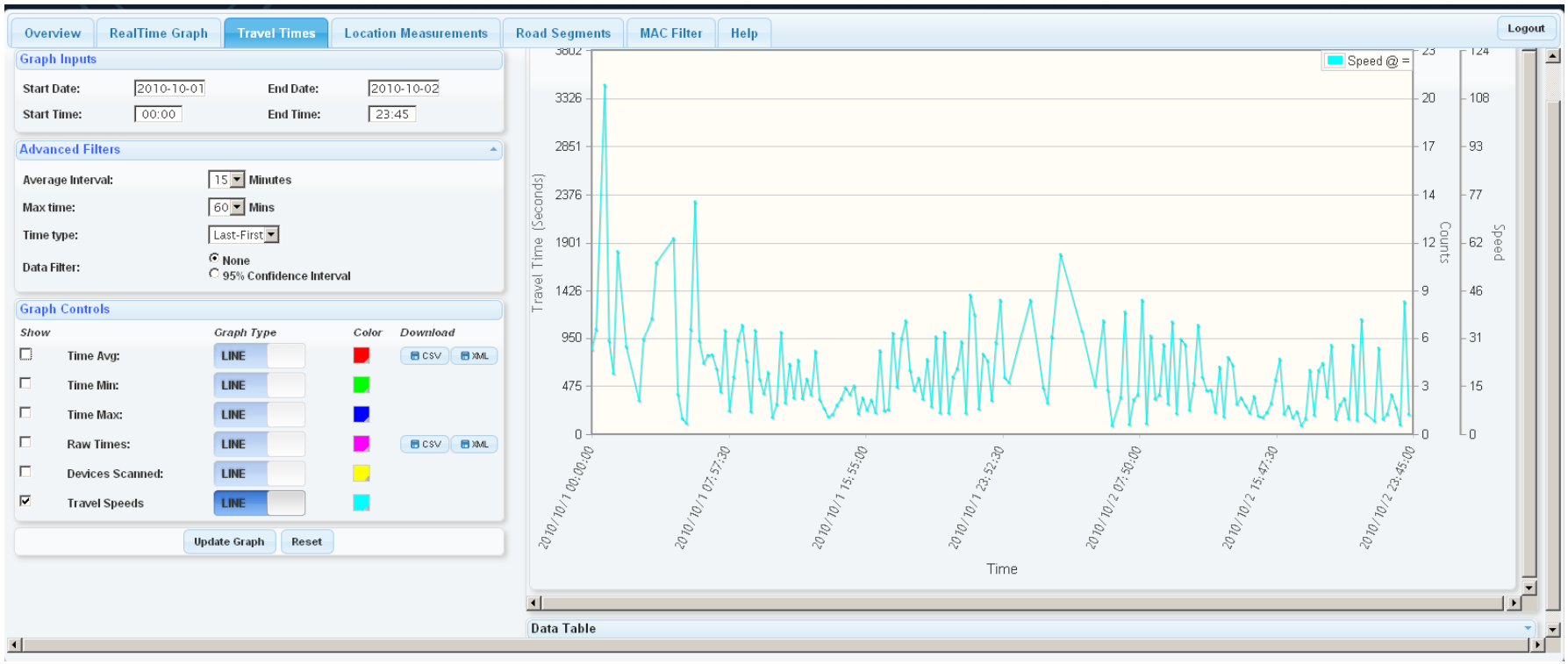


	BTMAC	First Seen	Last Seen	Seen Time	Device Type
1	00:00:B6:19:94:A0	2010-10-01 00:13:06	2010-10-01 00:14:56	110	Cellular (0204)
2	00:00:9D:BB:A2:F4	2010-10-01 00:13:56	2010-10-01 00:16:29	153	Smart Phone (020c)
3	00:00:B6:2A:9B:9F	2010-10-01 00:15:58	2010-10-01 00:18:31	153	Cellular (0204)
4	00:00:27:04:5C:C3	2010-10-01 00:23:33	2010-10-01 00:24:36	63	Laptop (010c)
5	00:00:91:3A:DE:F8	2010-10-01 00:26:44	2010-10-01 00:28:26	102	Cellular (0204)
6	00:00:36:26:5E:59	2010-10-01 00:53:32	2010-10-01 00:54:04	32	(0000)
7	00:00:B6:27:C8:ED	2010-10-01 01:05:34	2010-10-01 01:07:34	120	Cellular (0204)
8	00:00:D9:B3:4B:DC	2010-10-01 01:23:54	2010-10-01 01:26:58	184	Cellular (0204)
9	00:00:DC:01:20:FE	2010-10-01 01:34:06	2010-10-01 01:35:16	70	Smart Phone (020c)
10	00:00:7C:A6:58:6A	2010-10-01 01:39:00	2010-10-01 01:39:51	51	Smart Phone (020c)

5.1.7 VIEWING AVERAGE SPEED INFORMATION

The StreetWAVE server can also be used to display average travel speeds on a particular Road Segment (RSU). **Figure 17** shows a graph where the average speeds for a segment are displayed. The speeds are calculated based on the travel times that have been computed previously. The road segment lengths are taken from the RSU Segments tabs.

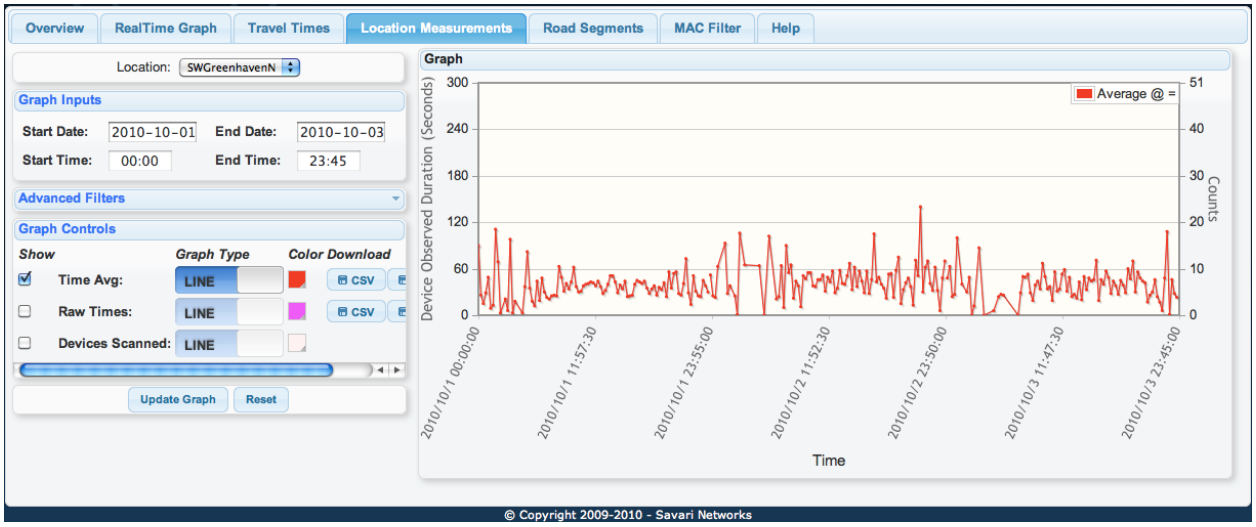
FIGURE 17. AVERAGE TRAVEL SPEEDS SCREEN



5.1.8 LOCATION MEASUREMENTS

This tab can be used to retrieve graphical data pertinent to the interval of time that BT devices have been seen at a particular RSU. This data is affected by the scan range of the RSU as well as the transmitting power of the BT device. Other factors such as congestion near the RSU can affect the interval of time that BT devices are seen in that vicinity.

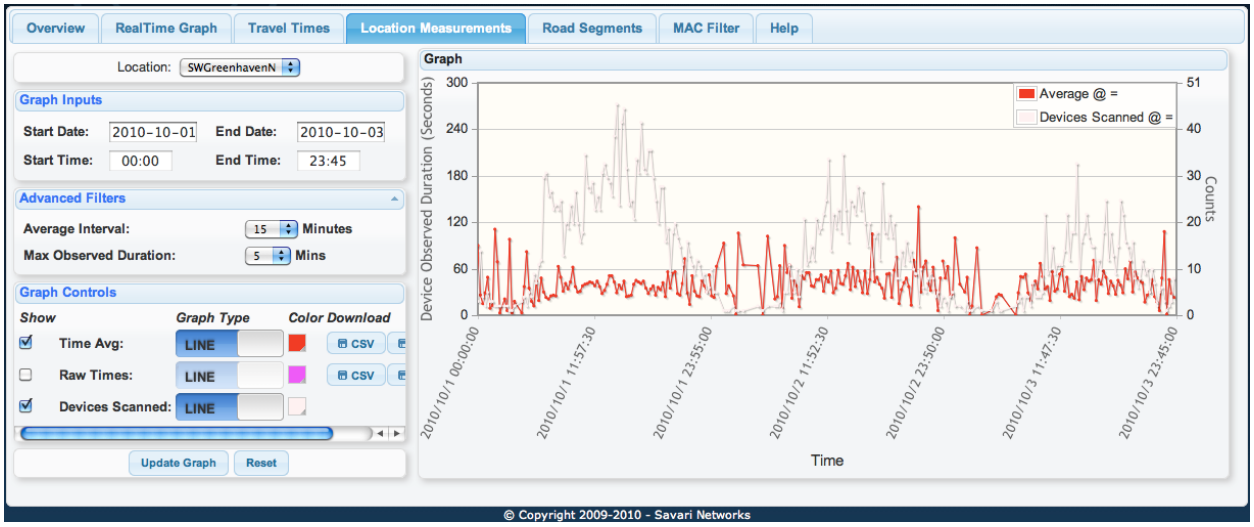
FIGURE 18. LOCATION MEASUREMENTS > AVERAGE TIME BT DEVICES SEEN AT ONE LOCATION



The average interval within the "**Advanced Filters**" corresponds to the interval over which the observed durations of BT devices are averaged. The "Max Observed Duration" is a filter that sets the upper limit.

Figure 19 shows the Location Measurement graph, displaying both the observed duration of the BT devices at an RSU along with the count of the number of devices scanned.

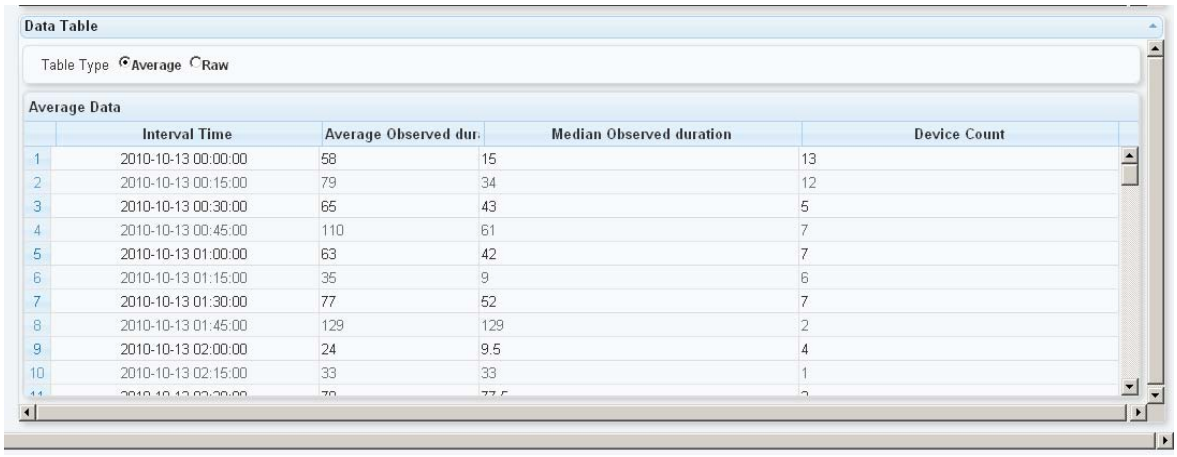
FIGURE 19. LOCATION MEASUREMENTS SHOWING DEVICES SCANNED AS WELL AS OBSERVED DURATION



A tabular display is also available to users. In the bottom right corner of the page, there is an arrow pointing to the bottom of the page. A table is displayed when the arrow is clicked. The user is able to select from two types of tables ('Average' or 'Raw'), which can be seen in **Figure 20**. The 'Average' table displays the following information:

- **Interval Time** – The period of time the user wishes to view results. The interval time can be changed in the Advanced Filters section (see **Figure 10**).
- **Average Observed Duration** – The average time that a MAC address was seen at one location during the given interval time.
- **Median Observed Duration** - The median time that a MAC address was seen at one location during the given interval time.
- **Device Count** – The amount of MAC addresses detected at a given location.

FIGURE 20. LOCATION MEASUREMENTS: TABULAR DISPLAY OF AVERAGE TABLE

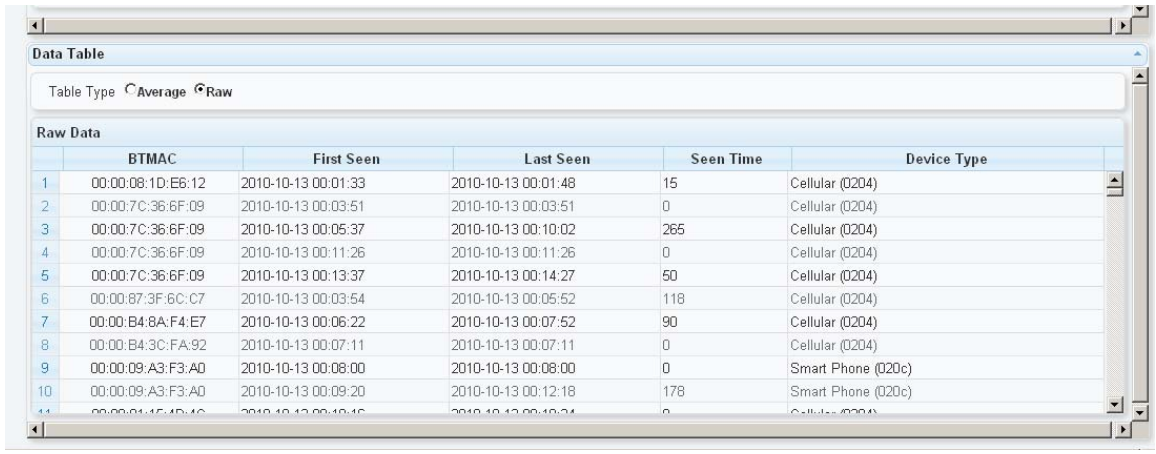


	Interval Time	Average Observed dur.	Median Observed duration	Device Count
1	2010-10-13 00:00:00	58	15	13
2	2010-10-13 00:15:00	79	34	12
3	2010-10-13 00:30:00	65	43	5
4	2010-10-13 00:45:00	110	61	7
5	2010-10-13 01:00:00	63	42	7
6	2010-10-13 01:15:00	35	9	6
7	2010-10-13 01:30:00	77	52	7
8	2010-10-13 01:45:00	129	129	2
9	2010-10-13 02:00:00	24	9.5	4
10	2010-10-13 02:15:00	33	33	1

The 'Raw' table can be seen in **Figure 21**. The 'Raw' table provides the following information:

- **BTMAC** – The MAC address that has been detected at this location.
- **First Seen** – The date and time that the MAC address was first seen at this location.
- **Last Seen** - The date and time that the MAC address was last seen at this location.
- **Seen Time** – The amount of time from when the MAC address was First Seen to the time it was Last Seen.
- **Device Type** – The type of device that the MAC address was pulled from.

FIGURE 21. LOCATION MEASUREMENTS: TABULAR DISPLAY USING THE RAW TABLE



	BTMAC	First Seen	Last Seen	Seen Time	Device Type
1	00:00:08:1D:E6:12	2010-10-13 00:01:33	2010-10-13 00:01:48	15	Cellular (0204)
2	00:00:7C:36:6F:09	2010-10-13 00:03:51	2010-10-13 00:03:51	0	Cellular (0204)
3	00:00:7C:36:6F:09	2010-10-13 00:05:37	2010-10-13 00:10:02	265	Cellular (0204)
4	00:00:7C:36:6F:09	2010-10-13 00:11:26	2010-10-13 00:11:26	0	Cellular (0204)
5	00:00:7C:36:6F:09	2010-10-13 00:13:37	2010-10-13 00:14:27	50	Cellular (0204)
6	00:00:87:3F:6C:C7	2010-10-13 00:03:54	2010-10-13 00:05:52	118	Cellular (0204)
7	00:00:B4:8A:F4:E7	2010-10-13 00:06:22	2010-10-13 00:07:52	90	Cellular (0204)
8	00:00:B4:3C:FA:92	2010-10-13 00:07:11	2010-10-13 00:07:11	0	Cellular (0204)
9	00:00:09:A3:F3:A0	2010-10-13 00:08:00	2010-10-13 00:08:00	0	Smart Phone (020c)
10	00:00:09:A3:F3:A0	2010-10-13 00:09:20	2010-10-13 00:12:18	178	Smart Phone (020c)

5.1.9 RSU SEGMENTS

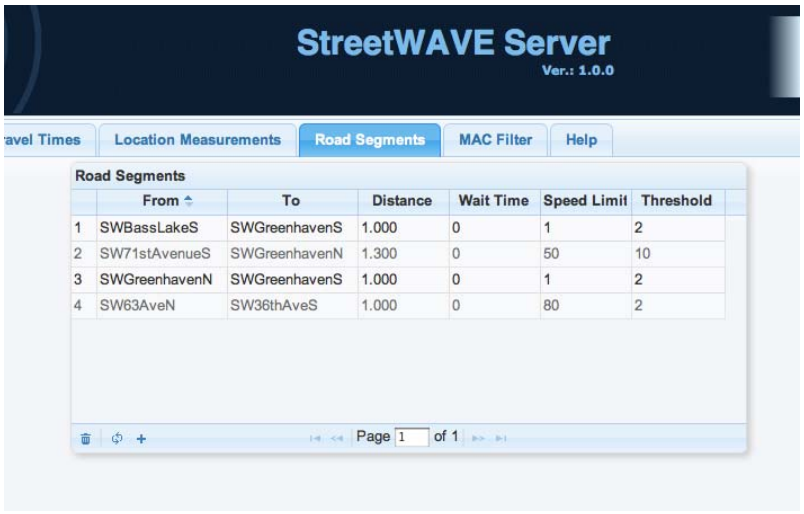
RSU Segments are defined as road segments that contain a unique start RSU and an end RSU. The traffic directionality is also determined by traffic flow in that order. Furthermore, other information such as length of the segment (distance), speed limits and wait times can be configured. The speed limit and wait time information may be used in the future to predict and inform motorists of potential traffic congestion ahead.

Figure 22 shows the list of configured segments.

The four columns shown in **Figure 22** are defined below:

- ***Distance*** – The distance (miles) between the source and destination RSUs.
- ***Wait Time*** – The maximum delay (seconds) between the source and destination RSUs.
- ***Speed Limit*** – The speed limit (miles per hour) between the source and destination RSU's.
- ***Threshold*** – This column is not currently used in the calculation of the travel times. It has been set up for future use in monitoring congestion.

FIGURE 22. RSU CONFIGURED SEGMENTS



RSU Segments can be added using the '+' button and deleted using the 'trash' icon. Editing/configuration of an RSU segment is shown in **Figure 23** below.

When creating a new RSU segment, it is important to complete the fields labeled 'Distance' and 'Speed Limit'. Both of these fields determine the 'Ideal Travel Time' which is used in the filtering process.

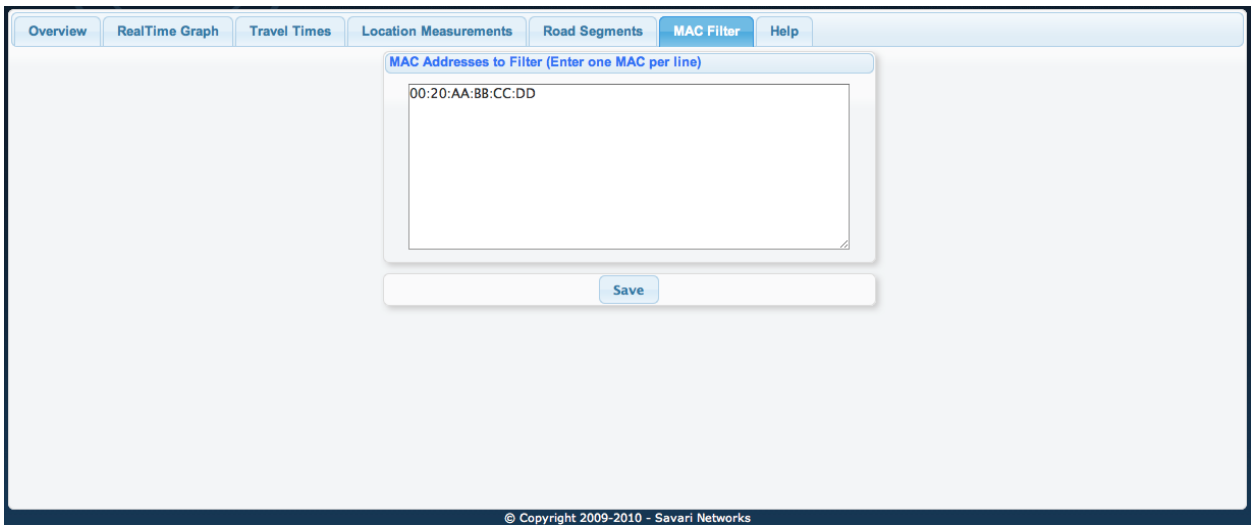
FIGURE 23. EDIT RSU SEGMENT SCREEN

5.1.10 MAC FILTER

The MAC Filter tab (**Figure 24**) can be used to filter all graphical data (location measurements, travel times and real time) for a specific BT MAC address. Savari envisions this feature to be used only for specific controlled test data. The MAC address needs to be entered in the universal MAC address format of 6 octets each of which is separated by a colon, e.g., AA:BB:CC:DD:EE:FF.

Any number of MAC addresses can be entered, but only one per line. MAC address entries can also be deleted and the resulting entries saved using the 'save' button.

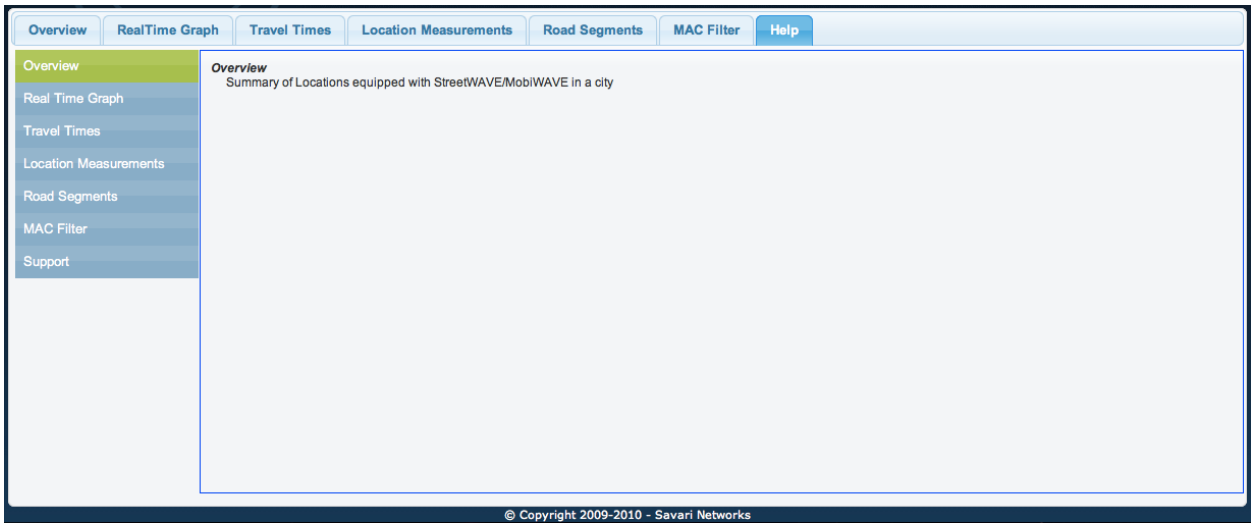
FIGURE 24. MAC FILTER SCREEN



5.1.11 HELP TAB

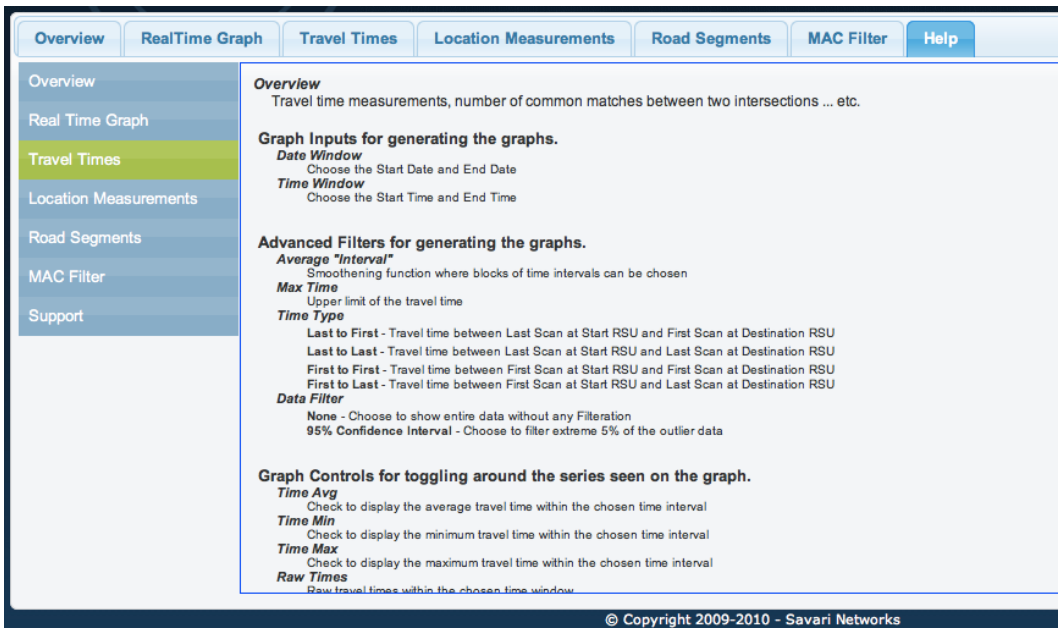
The "Help" tab provides information for each tab along with a summary of each configurable parameter. The Help tab is not intended to provide a very detailed explanation but rather a brief overview of each parameter.

FIGURE 25. HELP MENU SCREEN



Upon choosing the 'Help' tab, the various tab/menus are shown on the left side of the screen. Selecting any of these menus will pull up the help/definitions for all parameters on that page.

FIGURE 26. HELP MENU FOR TRAVEL TIME


Overview
RealTime Graph
Travel Times
Location Measurements
Road Segments
MAC Filter
Help
Overview
Real Time Graph
Travel Times
Location Measurements
Road Segments
MAC Filter
Support
Overview
Travel time measurements, number of common matches between two intersections ... etc.
Graph Inputs for generating the graphs.
Date Window
Choose the Start Date and End Date
Time Window
Choose the Start Time and End Time
Advanced Filters for generating the graphs.
Average "Interval"
Smoothening function where blocks of time intervals can be chosen
Max Time
Upper limit of the travel time
Time Type
Last to First - Travel time between Last Scan at Start RSU and First Scan at Destination RSU
Last to Last - Travel time between Last Scan at Start RSU and Last Scan at Destination RSU
First to First - Travel time between First Scan at Start RSU and First Scan at Destination RSU
First to Last - Travel time between First Scan at Start RSU and Last Scan at Destination RSU
Data Filter
None - Choose to show entire data without any Filteration
95% Confidence Interval - Choose to filter extreme 5% of the outlier data
Graph Controls for toggling around the series seen on the graph.
Time Avg
Check to display the average travel time within the chosen time interval
Time Min
Check to display the minimum travel time within the chosen time interval
Time Max
Check to display the maximum travel time within the chosen time interval
Raw Times
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5.2 TECHNICAL ASSISTANCE

During the project demonstration period, Iteris and Hennepin County Public Works jointly shared the technical assistance and troubleshooting duties for the StreetWAVE system along CSAH 81. Iteris staff was responsible for field troubleshooting in coordination with Savari Networks staff. Hennepin County Public Works personnel assisted Iteris and Savari Networks in the areas of StreetWAVE unit installation, troubleshooting (requiring the use of bucket trucks and other tools) and overall continual field maintenance duties.

For more information on the Savari StreetWAVE device technical requirements, users can go to the company's website at www.savarinetworks.com or contact Savari Networks by phone, fax or email. Please see contact information below.

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sales@savarinetworks.com

APPENDIX A

SAVARI STREETWAVE INSTALLATION GUIDE

Submitted by:

ITERIS®

ITS INNOVATIVE IDEA PROGRAM
ARTERIAL TRAVEL TIME MONITORING SYSTEM USING BLUETOOTH TECHNOLOGY

StreetWAVE Installation Guide

Submitted to:

Mn/DOT

January 2011

19-J09-1911

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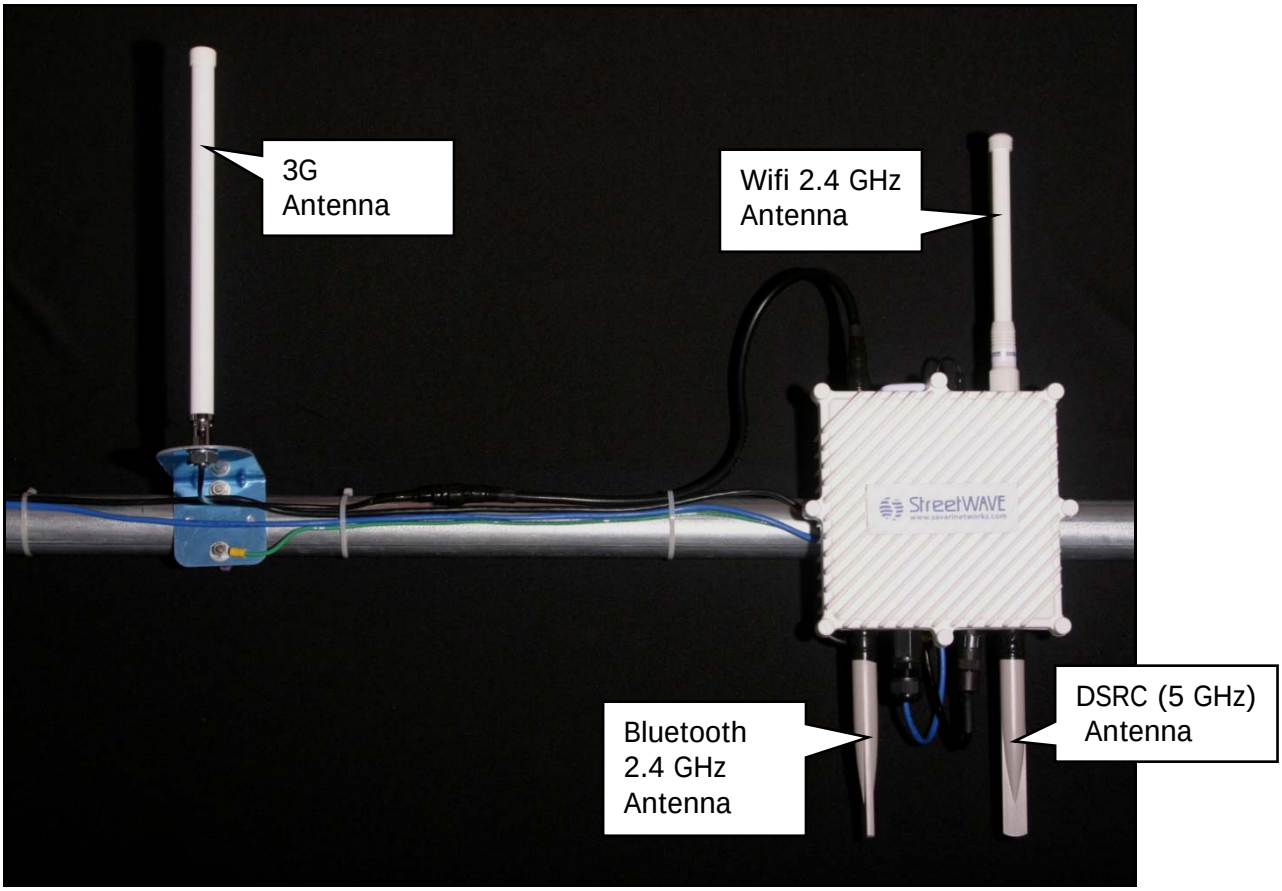

FIGURE 22: STREETWAVE AND 3G ANTENNA INSTALLATION

ANTENNA INSTALLATION AND SEALING

1. The StreetWAVE unit uses four antennas connected to the unit to collect and disseminate information. The antennas used can be seen in **Table 1**. The Bluetooth (2.4 GHz), Wifi (2.4 GHz) and DSRC should be connected directly to the StreetWAVE unit. The location where each antenna should be connected to the unit is labeled. The label included on the device is shown in **Table 1.** The final product configuration when mounted to the pole can be seen in **Figure 27.** Hand tighten the antenna connectors to the device, being careful not to over tighten. Do not over tighten. The GPS antenna is factory installed. For more information on the specifications of the antennas used, refer to Appendix A.

FREQUENCY/FUNCTION	LABELS
Bluetooth. 2.4GHz	BT
WiFi. 2.4GHz	WiFi
DSRC	5GHz
Cellular (Install on bracket)	3G

Table 1: Antenna Bands and Labels

2. Connect the RF Cable to the StreetWAVE at the 3G location. The RF Cable will be connected to the 3G antenna during installation.

3. Secure each antenna connector by wrapping self-sealing electrical tape (provided) around each antenna connectors and RF cable connectors to prevent water from entering the connectors. The wrapping should cover the entire StreetWAVE connector, antenna connector and at least two inches of the antenna cable. **Figure 28** shows an example of how the connectors should be secured by the electrical tape.

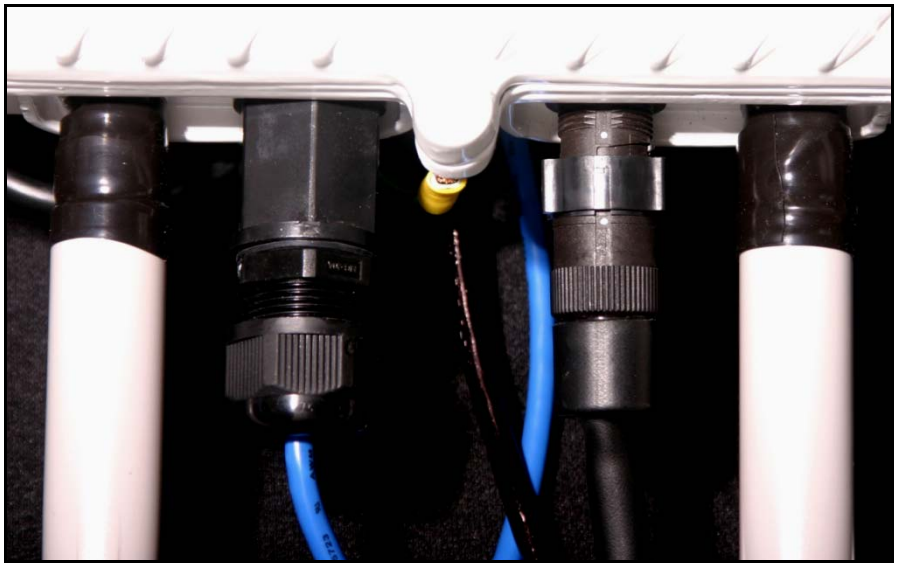

FIGURE 23: SEALED ANTENNA AND ETHERNET CONNECTORS

MOUNTING TO THE POLE

1. Install the mounting bracket to the back of the StreetWAVE unit. Use four (4) self-tapping screws (provided) and orient the bracket so the antennas are vertical, with the Wifi 2.4 GHz and RF Cable at the top of the device.

2. Secure the StreetWAVE unit to the pole using the Band-It mounting system. For more information on the Band-IT mounting system, refer to the following website: http://www.band-it-idex.com/en/index.html. The mounting bracket will accommodate a Band-It width of 1.2 inches.

3. Install the 3G antenna bracket two (2) feet away from the StreetWAVE unit. The U-bolt (provided) and bracket can accommodate poles up to 1¾ inches in diameter. After the bracket has been secured, place the 3G antenna on the mounting bracket and connect the RF cable to the 3G antenna connector. Hand tighten the 3G antenna connector to the RF cable, being careful not to over tighten. **Figure 29** shows the 3G mounting bracket with U bolt, locking bracket, nuts, flat washers and lock washers (provided with the antenna bracket). When installing the bracket, secure the ground wire lug under one of the bracket nuts.

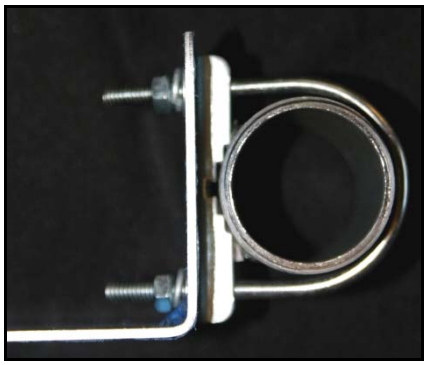

FIGURE 24: 3G MOUNTING BRACKET ASSEMBLY

.

CONNECTING POWER AND ETHERNET CABLES

1. Push the RJ-45 Ethernet connector through the sealing assembly provided with the StreetWAVE unit. Tighten the sealing nut until the rubber gland inside the nut is tightly compressed around the Ethernet cable. **Figure 30**.

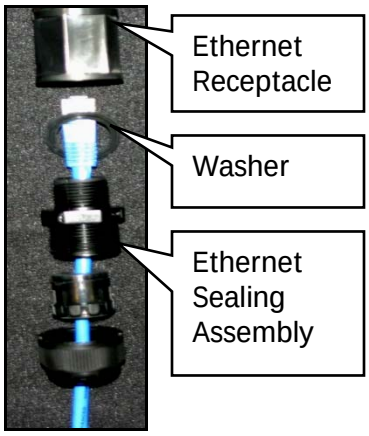

FIGURE 30: ETHERNET SEALING ASSEMBLY

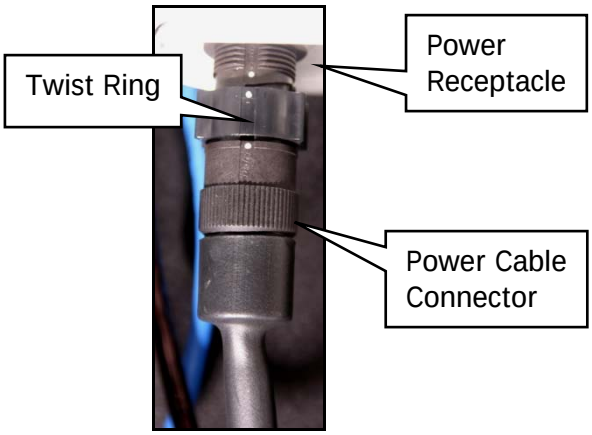

FIGURE 31: POWER CONNECTOR BEFORE TWISTING

2. Insert the RJ-45 into the Ethernet receptacle and press firmly to ensure it is connected.

3. Screw the RJ-45 sealing assembly into the receptacle. Ensure the rubber washer between the sealing assembly and receptacle remains flat and does not kink.

4. Connect the power cable to the StreetWAVE by aligning the white dots on the cable connector with the white dot on the receptacle. **Figure 31** shows how the connector cable is to be aligned with the power receptacle. Once the dots have been aligned, insert the cable connector into the receptacle and turn the twist ring (center dot) clockwise until it clicks.

SECURING CABLES

1. Connect the free end of the ground wire to the StreetWAVE unit using the screw between the power and Ethernet connectors as shown in **Figure 32**.

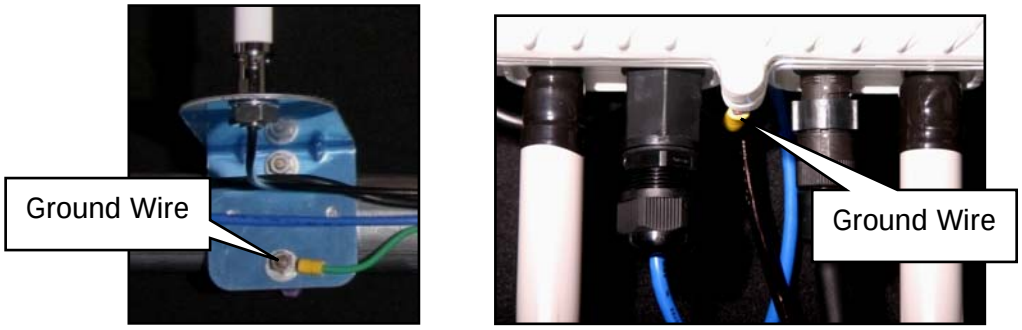

FIGURE 32: GROUND WIRE PLACEMENT: 3G MOUNTING BRACKET (LEFT) AND STREETWAVE UNIT (RIGHT)

2. Position the power and Ethernet cables so they are not near the antennas. Secure the cables behind the StreetWAVE unit using wire ties or electrical tape. Only use wire ties that are weather resistant and rated for outdoor use.

3. Use wire ties to secure the 3G antenna cable, power cable and Ethernet cable to the mounting surface as shown in **Figure 27**.

SERIAL PORT

1. The serial port on the side of the StreetWAVE is for diagnostic use only. It should remain covered by the factory installed cap.

REMOVAL AND STORAGE

1. To remove the power connector, twist the twist lock ring (shown in **Figure 31**) counter-clockwise until the three (3) white dots are aligned. Pull the power cable straight out from the power receptacle.

2. Unscrew the Ethernet sealing assembly. Using a small, standard screwdriver, depress the RJ-45 locking tab inside the Ethernet receptacle and gently pull the cable to disconnect the cable.

3. Remove the self-sealing tape from the 3G RF extension cable by slitting the tape and peeling it away from the connectors and cables. Disconnect the 3G antenna cable from the extension cable.

4. Unbolt the 3G antenna bracket to remove it from the pole.

5. Carefully remove the StreetWAVE unit from its mounting position by cutting the Band-It straps. While cutting the Band-It straps, it is important that the StreetWAVE is being held by the person cutting the straps to prevent the unit from being dropped.

6. Once the StreetWAVE unit has been removed from its mounting position, remove the self-sealing tape by slitting the tape and peeling it away from the connectors and cables. Unscrew each of the antennas and place them and the StreetWAVE unit in a box for storage.

ANTENNA SPECIFICATIONS

Wireless 5Ghz Antenna

2.4 / 5 GHz Dual Band Omni Antenna N Male [ANT-5G-7-OMNI-NM]

- Peak gain 7 dBi @ 5 GHz
- Peak gain 4.5 dBi @ 2.4 GHz
- Waterproof design for outdoor use
- Straight N Male connector

The rugged ABS body makes this antenna suitable for use in a wide variety of applications, including office LAN environments, factory floors, remote telemetry and outdoor environments.

Electrical Specifications:

- Peak Gain: 7 dBi @ 5150 - 5875 MHz
- Peak Gain: 4.5 dBi @ 2400 - 2500 MHz
- Impedance: 50 Ohm VSWR: 2.0:1 Max
- Polarization: Vertical, Linear hpbw/horizontal / vertical: 30 degrees @ 2.4GHZ, 15 degrees @ 5 GHz
- Maximum power: 2 W

Environmental & Mechanical Characteristics:

- Survival wind speed: 216 km/hr
- Temperature Range: -40C to +70C
- Humidity 95% @ 55C Radome color: Gray
- Radome material: ABS
- Weight: 70 gw
- Dimensions: 22 x 183 mm

Bluetooth Antenna

2.4 GHz 6 dBi
RP-SMA Omni-directional Wireless LAN Antenna

Electrical Specifications

- Frequency 2400-2500 MHz Gain
- 6 dBi Type OMNI
- Beamwidth deg. Horz. 360° Vert 20° SWR 1.8 : 1 max
- Power handling 50w(cw)
- Mechanical Specifications Weight 1.2 Kg Size
- H 1260 x D 40mm
- Material Fiberglass Connector
- N-Female Polarization
- Linear Vertical Temperature -40°c ~ +80°c

3G Antenna

Electrical Specifications

- Frequency Range 806-894 / 1850-1990
- Impedance 50 Ohms Antenna
- Gain 5.12 dBi 806-894 / 6.12 dBi 1850-1980 Max
- Power 25 watts
- Height 18"" (Antenna) Connector
- FME female Mount
- Pole mount